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BUILT DYE-SENSITIZED SOLAR CELLS- A CONFIRMATORY TEST OF A MATHEMATICAL MODEL

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ABSTRACT

In their work, Efurumibe, et al (2012) developed a mathematical model of electron transport through the anode of a standard dye-sensitized solar cell. By analysis of the model, it was observed that the rate of electron trapping by the anode of the dye-sensitized solar cell decreases as the anode side increases. Here in this work, three different dye-sensitized solar cells (of different anode sizes) were built. When the cells were tested, it was observed that the cells with higher anode sizes gave increased current and voltage values. This confirmed the mathematical model as true.

Key Words: Dye, Sensitized, solar, Cell, Efurumibe

1. INTRODUCTION

Dye-sensitized solar cells are nanoparticulate photovoltaic cells that mimic the photosynthetic process in solar-to-electricity conversion (Reijnders, 2009). Dye sensitized solar cells offer the prospect of very low-cost fabrication and present a range of attractive qualities that will facilitate market entry (Grätzel and Durrant, 2008). In most cases, the dye-sensitized solar cell is called in conjunction with the word: "mesoscopic" as dye-sensitized mesoscopic solar cell. The word mesoscopic refers to a small scaled size (usually nanoscaled size). The standard dye-sensitized solar cell has its anode as titanium dioxide and is often times called: Gratzel cell (Reijnders, 2009). This is because Michael Grätzel was the one who first developed a workable dye-sensitized solar cell based on Titanium oxide anode and a Rheutenium dye. Grätzel received a millennium technology prize award for his work in 2010 (Hollister, 2010).

The progress realized recently in the fabrication and characterization of nanocrystalline materials has opened up vast new opportunities for the dye-sensitized solar cells. The dye-sensitized mesoscopic solar cells realizes optical absorption and charge separation processes by the association of a sensitizer as light-absorbing material with a wide-bandgap semiconductor (TiO_2) of nanocrystalline morphology (O'Regan and Grätzel, 1991). Dye-sensitized solar cells are said to be photo-electrochemical cells that make use of electrolytes along with a semiconductor in their operation. The process of solar-to-electricity conversion in dye-sensitized solar cell mimics photosynthesis process.

In their work, Efurumibe et al (2012) developed a mathematical model of electron transport through the anode of a standard dye-sensitized solar cell. By analysis of the model, it was observed that the rate of electron trapping by the anode of the dye sensitized solar cell decreases as the anode side increases. The work done here confirmed that the analysis was true.

2. BUILDING THE DYE-SENSITIZED SOLAR CELLS

In building the dye-sensitized solar cells, first titanium dioxide (TiO_2) suspension was first prepared. This TiO_2 suspension was then used to coat three different conductive glass slides for various thicknesses: 50µm, 100µm and 150µm. After which the TiO_2 was annealed each to the glass slides at a temperature of 450^oC, using a furnace in the MOUAU Physics labouratory. These glass slides were later stained with anthocynin dye prepared from Momordica Charantia seed (see fig.1). While the glass slides were being stained, three other glass slides (to serve as counter electrodes) were coated with carbon from the carbon pencil provided. These counter electrodes were then coupled with the stained anodes to form the dye-sensitized solar cells. The solar cells were completed after the electrolyte (iodine) was added. After which the solar cells were illuminated under full sun light and the readings of the open circuit voltages and currents noted.

3. RESULT

Under full sunlight, the value of the voltages and currents of the cells were as follows: For the cell with the 50µm thick anode, the voltage obtained was: 0.492V while the current was 3mA. For the cell with 100µm thick anode, the voltage was: 0.568V while the current obtained was 4.5mA. For the cell with 150µm thick anode, the voltage was: 0.6V while the current obtained was 6mA. These values were obtained using digital and analog multimeters.

4. CALCULATING THE EFFICIENCIES OF THE SOLAR CELLS

The power (P_s) of incoming solar radiation under full sunlight has been calculated to be: 80mW/cm^2 (Fanis, 2010). Again electrical power is calculated as the product of voltage and current (Ndupu and Okeke, 2002). The area (A) of the conductive glass slide covered with TiO_2 is approximately 2cm x 2cm = 4cm^2.

Thus we calculate the power per unit area (P_{a1}) for the first cell (with anode thickness: 50µm):

$P_{a1} = (V_1 \times I_1)/A = (0.492 \times 3)/4 = 0.369$mW/cm^2.

The incoming solar-to-electricity conversion efficiency (E) is thus calculated from the formula (Fanis, 2010):

$E_1 = P_{a1}/ P_s \times 100\% = 0.369/80 \times 100\% = 0.46\%$

For the second cell, the power per unit area (P_{a2}) is calculated as:

$P_{a2} = (V_2 \times I_2)/A = (0.568 \times 4.5)/4 = 0.639$mW/cm^2

$E_2 = P_{a2}/ P_s \times 100\% = 0.639/80 \times 100\% = 0.80\%$

For the third cell, the power per unit area (P_{a3}) is calculate thus:

$P_{a3} = (V_3 \times I_3)/A = (0.6 \times 6)/4 = 0.9mW/cm^2$

$E_3 = P_{a3}/P_s \times 100\% = 0.9/80 \times 100\% = 1.13\%$

5. DISCUSSION

The results obtained from the physical dye-sensitized solar cell (see session 3) agree well with the result of the mathematical model. It can be observed that the cell with anode thickness 50µm gave a voltage value of 0.492V and current value of 3mA. The cell with anode thickness 100µm gave a voltage value of 0.568Vand a current value of 4.5mA. The third cell with anode thickness of 150µm gave a voltage value of 0.6V and a current value of 6mA. It can be observed from the result that the thicker the anode, the more electrons can flow through it. Also the more efficient the cell becomes. This is true looking at session 4. The efficiency of the first cell was lower than the efficiency of the second and that of the second lower than that of the third. This confirmed the result of the mathematical model and went ahead to reiterate the fact that increasing the thickness of the anode would help improve the efficiency of the standard dye-sensitized solar cell.

REFERENCES

Efurumibe, E.L., Asiegbu, A.D. and Onuu, M.U. (2012). Mathematical modeling of electron transport through the anode of a standard dye-sensitized solar cell, Asian Journal of Applied Sciences, 5(1): 33-42

Fanis, L. (2010). Nanocrystalline solar cell kit Recreating Photosynthesis, ICE publication, pp52

Grätzel, M. and Durrant, R.J. (2008). Dye-sensitized Mesoscopic solar cells, Giacomo Ciamician, New york pp.217

Hollister, S. (2010). Michael Grätzel, inventor of the dye-sensitized solar cell, wins 2010 Millennium Technology Prize, accessed on 10/07/2011 from: http://www.engadget.com

Ndupu, B.L.N. and Okeke, P.N. (2002). Round-up Physics A Complete Guide, Longman Nigeria Plc, pp 220

O'Regan, B. and Grätzel, M. (1991). A low cost, high-efficiency solar cell based on dye-sensitized colloidal TiO_2 films, Nature 353, pp 737-739

Reijnders, L. (2009). Design Issues for Improved Environmental Performance of Dye-sensitized and Organic Nanoparticulate solar cells, Journal of Cleaner Production, 18 (2010): 307-312.

Fig. 1: Glass slides placed faced down in anthocyanin